MODELING IN SUPPORT OF MANAGEMENT OF COASTAL HYPOXIA AND ACIDIFICATION IN THE CALIFORNIA CURRENT ECOSYSTEM

December 10 - 11, 2013
Workshop Proceedings

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MODELING IN SUPPORT OF MANAGEMENT OF COASTAL HYPOXIA AND ACIDIFICATION IN THE CALIFORNIA CURRENT ECOSYSTEM

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Martha Sutula and Meredith Howard
Southern California Coastal Water Research Project Authority

Larry Crowder
Center for Ocean Solutions

Skyli McAfee
California Ocean Science Trust

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Table of Contents

EXECUTIVE SUMMARY

Overview

The US West Coast has experienced an increasing number of hypoxia/acidification events severe enough to affect coastal marine ecosystems. The primary drivers for this trend are processes that operate at a global scale, but there are several management actions that can be taken at the regional scale to either reduce the rate of hypoxia/acidification or lessen the effects of these events on the coastal marine ecosystem. Determining the likely effectiveness of regional management actions requires coupled biogeochemical and physical circulation models that presently don't exist for near coastal environments. Furthermore, it is not even clear whether the types of data necessary to calibrate and validate such models with adequate accuracy to support management action are available. Moreover, funding for model development is often siloed by topic (e.g., hypoxia, acidification, harmful algal blooms) or region, with a lack of interregional and interdisciplinary studies directed at linking management across the West Coast.

To stimulate development of models that address hypoxia/acidification management needs, a two-day workshop involving state and federal managers, industry representatives and leading academic researchers was held in Costa Mesa, California on December 10 - 11, 2013. The workshop featured two breakout sessions in which participants were tasked to identify the most significant impediments to developing models and to create a prioritized list of actions to overcome these impediments while focusing on two management questions:

1. What is the relative contribution of local anthropogenic nutrient inputs to coastal hypoxia and acidification?

2. What geographic locations are the most susceptible to hypoxia and acidification?

The participants reconvened in a general assembly at the conclusion of each of the breakout sessions to summarize discussions and form consensus regarding conclusions. The workshop ended with a plenary discussion to coalesce the workshop's primary findings and recommendations.

Significant Workshop Findings and Recommendations

The workshop produced two major findings:

1. The participants concluded that there are no significant technical impediments to developing models that will answer both management questions. However, answering these questions will require investment of resources. Still, calibration data are available and preliminary modeling has been conducted for several coastal regions. These data and modeling efforts can be used to provide preliminary information about the importance of local anthropogenic nutrient inputs to hypoxia/acidification managers and guide future expenditures of resources to address these questions in other regions.

2. The question of regional susceptibility to hypoxia/acidification events is more challenging and will require more investment to answer than the question about anthropogenic nutrient inputs. Workshop participants recommended focusing on the nutrient question, as the actions needed to address the question of the importance of local anthropogenic inputs will ultimately improve the modeling baseline needed to answer the susceptibility question.

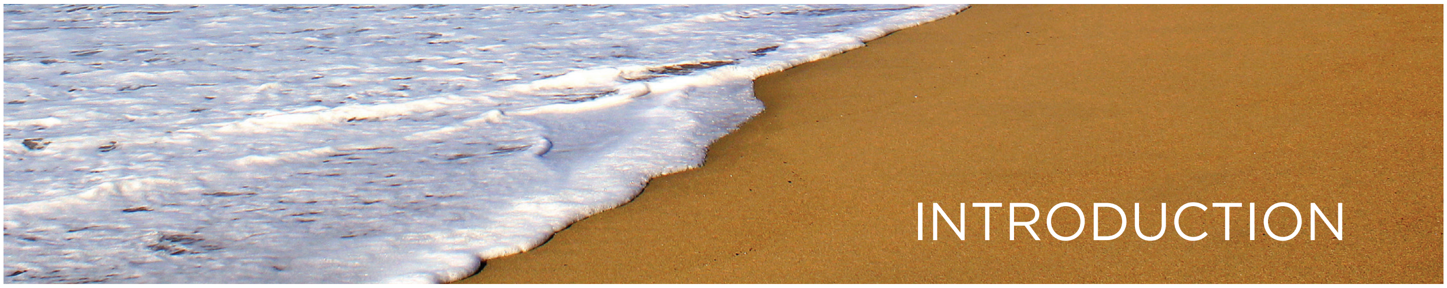
Based on these conclusions, the workshop participants agreed there is a logical set of actions that should be conducted, the most prominent of which are:

- Build a community of modelers, observational researchers, and managers that: 1) encourages dialog among sectors about model outputs necessary to address management endpoints and underlying policy decisions, 2) facilitates discussion about the level of model validation needed for making management decisions, and 3) serves as a vehicle for coordination of modeling products among different technical specialists. Participants noted a lack of clarity about the management decision endpoints that this interaction forum would help clarify as interim products were developed, and ensure cost-effective allocation of modeling and data collection activities.

- Use existing models to begin bounding the problem. This is best done through a model comparison. There are multiple approaches for addressing these questions and a comparison of outcomes from different approaches would provide multiple lines of evidence that constrain uncertainty in the answer. This model comparison should be conducted in a focused geographical region(s) and based on shared observational records and specific statistical measures that could be used to test various models. This comparison should be collaborative and ideally lead to integrated approaches.

- Collect observational data to support model refinement, including observations of oceanic state for model validation and short-duration, intensive monitoring to constrain key biogeochemical rate processes. This should go in tandem with a central repository for observational data and model output to provide open access and encourage research community participation.

Workshop participants also stressed the need for sustained research funding for basic science, including modeling, observational, and experimental studies to investigate the factors driving hypoxia/acidification events and their ecological effects.



INTRODUCTION

Global oceans have become increasingly hypoxic (low oxygen) and acidic (low pH) primarily due to increasing levels of atmospheric carbon dioxide. Upwelling-dominated coastal regions, such as the California Current Large Marine Ecosystem (CCLME), are particularly affected because upwelling events periodically draw deep, low oxygen, low pH waters into shallow coastal areas. These events are severe enough to affect biotic resources, which has raised concern about impacts on the coastal ecosystem that support a tremendous biodiversity and important economic sectors, such as fisheries.

To address increases in hypoxia/acidification events, the State of California has partnered with the States of Oregon and Washington and the province of British Columbia to form a panel of scientific experts charged with summarizing the state of knowledge about conditions in the CCLME. As part of that effort, the California Ocean Science Trust assessed the information needs of manager's concerned with hypoxia/acidification and two key questions were identified:

1. To what extent do local anthropogenic nutrient inputs exacerbate the problem? Managers have expressed interest in better understanding the linkage between anthropogenic nutrient inputs and resulting effects on coastal hypoxia and acidification, because nutrient control represents one of the few potential management actions to reduce effects at the local level. The cost of instituting controls on anthropogenic inputs is expected to be in the billions of dollars and managers need increased certainty about whether nutrient controls will lead to a meaningful environmental response.

2. Which areas of the coast are more susceptible than others to hypoxia and acidification? The west coast states all engage in some form of spatial planning, whether for fisheries management, industrial or mariculture applications. Knowing which areas are most susceptible to hypoxia and acidification, either through upwelling of deep water or through increased productivity due to anthropogenic nutrient inputs, will help with these planning processes.

Addressing these questions requires coupling biogeochemical models and physical circulation models that yield three key products: 1) modeling output that identifies the spatial and temporal scales at which current and future (projected) anthropogenic inputs have a significant effect on productivity, hypoxia, and acidification, 2) analyses quantifying the net change in hypoxia and acidification versus cost associated with different scenarios of controls on anthropogenic inputs, and 3) maps identifying susceptibility of regional coast zones to hypoxia and acidification based on oceanographic properties and anthropogenic inputs.

Coupled models capable of achieving these key products presently don't exist. Further, it is not clear whether the types of data necessary to calibrate and validate such models with adequate accuracy to support management action are available. Moreover, research funding for modeling and observations studies to investigate hypoxia and acidification is often siloed by topic (e.g., hypoxia, acidification, harmful algal blooms) or by region, with a lack of funding opportunities for interregional and interdisciplinary studies directed at linking issues across the West Coast.

Workshop Goals

To stimulate development of coupled biogeochemical and physical circulation models that address key management needs, the Center for Ocean Solutions and the California Ocean Science Trust sponsored a workshop involving state and federal managers, industry representatives and leading academic researchers. The objectives of the workshop were to:

- Encourage discussion and interaction among management, industry, and research communities affected by ocean hypoxia and acidification

- Determine the key impediments to using models to address key management questions and concerns

- Identify a list of actions and research needs required to overcome the impediments identified

Workshop Structure

The workshop was held at the Southern California Coastal Water Research Project Authority (SCCWRP) in Costa Mesa, California on December 10 - 11, 2013. There were 35 invited participants, including leading researchers with expertise in coastal modeling and physical/biogeochemical oceanography, state and federal resource managers, US West Coast Ocean Observing Systems representatives, and a shellfish fishery manager (see Appendix B for a list of workshop participants).

The workshop began with two plenary presentations that introduced the present state of knowledge about hypoxia and acidification on the US West Coast (see Appendix A for the workshop agenda). Next, there were three presentations by management representatives from water quality, fisheries and shellfish, and science/policy coordinating entities. These presentations summarized managers' perspectives and informational needs with respect to hypoxia and acidification. These were followed by seven presentations about the present state of modeling in the California Current Ecosystem on spatial scales ranging from pacific basin to regional to local.

Two breakout sessions followed these presentations. The first breakout session was intended to identify impediments to using or developing models that address questions about the importance of local anthropogenic nutrient inputs on hypoxia and acidification. The second breakout session focused on identifying impediments to defining geographic locations that are most susceptible to hypoxia and acidification. The participants reconvened at the conclusion of each breakout session to summarize discussions and form consensus about conclusions and recommendations.

BREAKOUT SESSION SUMMARIES

Findings from Breakout Session 1: The Importance of Anthropogenic Inputs to Hypoxia and Acidification

The first breakout session focused on the importance of local anthropogenic nutrient inputs in exacerbating hypoxia and acidification, with a charge to:

1. Identify the most significant impediments to developing models (or use of current models) to address the following management questions:
   a. What is the relative contribution of local anthropogenic nutrient inputs to coastal hypoxia and acidification?
   b. How would current hypoxia and acidification events might be mitigated if local anthropogenic nutrient sources were reduced?

2. Develop a long-term strategy and a prioritized list of actions to overcome these impediments.

The participants concluded that there were no significant technical impediments to model the relative contribution of anthropogenic inputs on hypoxia and acidification. They felt that developing models to address the manager's questions with a high level of certainty will involve substantial investment, but that ocean models and data to begin that process already exist along several regions of the coast. Four regions were identified as having existing ocean models and data to begin pursuing these questions: 1) Southern California Bight, 2) Monterey Bay, 3) Columbia River and 4) Puget Sound. These existing models and data can be used to provide preliminary information to managers, which can then guide future expenditures of resources to gain more precise answers.

Participants identified numerous actions that could be conducted in the short- (less than a year), near-term (1 - 2 years), and long-term (2 - 5 years) to help achieve manager's needs. The short-term, actions identified included:

- **Better define management endpoints for hypoxia and acidification.** While no technical impediments exist to model hypoxia and acidification, participants noted a lack of clarity about the management endpoints for hypoxia and acidification. In particular, modelers wanted to know whether the modeling outcome should focus on the average value of the endpoint (e.g., aragonite saturation state, dissolved oxygen) or the extreme values. If the extreme is the required focus of the model, is it the magnitude, frequency or duration of an extreme event, as this drives the spatial and temporal scales at which the models need to be developed. Workshop participants recommended building a community of modelers, observational researchers, managers and stakeholders that educate researchers on the key scientific questions underlying policy decisions on endpoints.

- **Validate existing models to identify key gaps in data and modeling infrastructure.** A nested set of numerical physical and, to a lesser extent, biogeochemical models, exist for the US West Coast, from the Pacific Basin, regional and in some regions, local scale. However, few have been validated and data are already available in several places for this validation. Workshop participants recommended that this validation be conducted to quantify uncertainty and identify key gaps in data and modeling infrastructure. Quantification of uncertainties will serve to inform the discussion on the precision required to answer this question in the near-term and help to further focus resources on model refinement.

- **Use existing numeric models and other simple box or statistical models to identify sub-regions along the coastline where anthropogenic nutrients are most likely to have an impact.** Anthropogenic nutrients could have an impact either because their magnitude is large relative to ocean nutrient sources and/or the coastal circulation patterns result in extended residence time of these inputs, allowing blooms to develop. The workshop participants recommended that existing models be utilized to quantify those factors and identify sub-regions along the coastline that would be susceptible to anthropogenic nutrient inputs. This would not only begin to provide answers to the management community, but would also start to constrain the locations where more advanced models to better quantify those effects are most appropriately focused.

In the near-term, participants recommended a set of actions that would follow logically from those above:

- **Extend existing offshore models to the nearshore.** Circulation models at the pacific basin or regional scale exist, but few have been extended into the nearshore zone. Coupling of the nearshore and offshore models is important, because the nearshore is where OA and hypoxia are likely to have impacts on habitats or species of greatest management concern and where local management actions would be focused.

- **Collect data to support model development and refinement.** Observational data were identified by workshop participants as a key need to model refinement and validation. Two major types of data were identified: 1) Observations of oceanic state for model validation. Numerical models predict physical and biogeochemical variables that represent oceanic state in time and space (e.g., salinity, temperature, dissolved oxygen, pH). Observational data that document these patterns (e.g., CTD casts, moorings and gliders) are critical for model validation and uncertainty analysis. Workshop participants stressed that the nearshore surf zone was a key data gap for model validation; observations of deep waters that are the source of upwelling were also highlighted. 2) Biogeochemical rate processes. Models are simplified representations of complex biophysical interactions, expressed through model equations and their parameters. The biogeochemical rate processes (e.g., productivity, respiration, benthic flux, nitrification, etc.) used in present models are based on globally derived estimates, mostly from open oceanic settings, and workshop participants indicated that models would be more appropriately parameterized using rate processes specific to the nearshore and local geography.

- **Create a central repository for observational data and model output.** Workshop participants recommended the support of an integrated data repository to provide open access to observational data and modeling results. This was deemed key to advance the science of modeling and promote communication among the research and management community.

- **Support a model comparison.** There are multiple approaches for addressing this question and participants felt that a comparison of outcomes provided by different approaches would provide multiple lines of evidence that constrain uncertainty in the answer. This model comparison should be conducted in a focused geographical region(s) and based on shared observational records and specific statistical measures that groups could use to test their own models. Workshop participants stressed that this comparison should be collaborative, rather than competitive, hopefully leading to integration of these different efforts. It should also be transparent, so that the modeling community has the ability to weigh in on the strengths and weaknesses of modeling approaches and uncertainty in modeling outcomes.

Over the long-term, workshop participants stressed the need for sustained research funding for basic science, including modeling, observational and experimental studies, to investigate the factors driving hypoxia and acidification as well as their ecological effects. Currently research in this area is often siloed by topic (e.g., hypoxia, acidification, harmful algal blooms) or by region, with a lack of funding opportunities for interregional and interdisciplinary studies aimed at linking issues across the West Coast. This research would also contribute ultimately to refining models, reducing uncertainty, and further identifying of key data gaps.

Findings from Breakout Session 2: Identify and Forecast Areas of Susceptibility to Hypoxia and Acidification

The second breakout session focused on identification of the most susceptible areas on the US West Coast to hypoxia and acidification. The objectives of the second breakout session were the following:

1. Identify the most significant impediments to use models to identify and forecast areas of susceptibility to hypoxia and acidification on the US West Coast:

    a. What geographic locations are the most susceptible to hypoxia and acidification?
    b. Which areas are susceptible to factors under local control versus factors that are a result of global processes?

2. Develop a long-term strategy and prioritized list of actions to overcome these impediments. The participants started this discussion by asking for clarification of the charge, recognizing that the answers depended on the spatial and temporal scale of the vulnerability under consideration. They pointed out that a vulnerability assessment of for an oyster hatchery would depend on daily pH forecasts at a specific location, whereas climate-responsive management of commercial and recreational fisheries stocks would likely require models that produce coast-wide forecasts of hypoxia and acidification over timescales of years to decades. Participants were given freedom to address the question from a variety of spatial and temporal scales, but were told that the primary driver for this question should be effective marine protected areas management and they should focus on scales appropriate to that application.

The participants concluded that, as in the first management question, there are no significant technical impediments to addressing the management questions. However, they also concluded that these questions are more challenging to address, for two major reasons:

- **Forecasting is more technically challenging and resource intensive.** Predicting susceptibility requires forecasting, which is technically more difficult and more resource intensive, particularly if it involves data assimilation modeling. Additionally, the spatial and temporal scales at which the models must be run are more encompassing. Spatially, this question would require modeling the entire US West Coast, rather than focusing on a specific region, as would be the case for the anthropogenic nutrient question addressed in the first breakout session. The temporal scale is also more challenging because it would likely require output on daily-weekly timescales to capture extremes. In particular, those extremes might also require incorporation of diurnal variability in the models, especially in the nearshore-surf zone, which present models are not constructed to do. Capturing diurnal variability is important because pH and DO are characteristically lower in the night than in the day.

- **Susceptibility and relationship to vulnerability to marine resources has not been well defined.** Workshop participants felt that it possible to produce maps of the distribution of DO and pH concentrations in many regions along the US West Coast. However, "susceptibility" can be defined in various ways, from species-specific to community scale for a variety of estuarine and marine habitats. These habitats range from estuarine to marine, from intertidal to subtidal, benthic and pelagic, including seagrass beds, kelp forests, rocky reefs, etc. Managers have not adequately defined "susceptibility" and how it links to assessment of vulnerability of estuarine marine resources.

For these reasons, participants felt that it was more expedient to initially focus resources on the first question. However, there are several concrete actions that could be achieved in the short-, near-, and long-term. Workshop participants stressed that investing in the short- and near-term steps identified for the first breakout session (anthropogenic nutrients) would also result in improved capacity to forecast susceptibility.

Over the short-term, actions identified included:

- **Use existing numeric models and other simple box or statistical models to produce maps of dissolved oxygen and aragonite saturation state at a variety of spatial and temporal scales.** The workshop participants recommended existing numerical and simple statistical or box models be used to identify sub-regions along the coastline that are "hot spots" for hypoxia and acidification. This exercise can include the scenarios from the Intergovernmental Panel on Climate Change (IPCC), already completed at a pacific-basin scale for aragonite saturation state, downscaled to finer resolutions. These maps could be produced during the course of model validation, along with estimates of uncertainty in model prediction. The maps can also be attributed with local factors that could contribute to or mitigate susceptibility, such as anthropogenic nutrient inputs or extensive seagrass beds. These maps can be used to further inform discussions of how to define susceptibility and how this relates to vulnerability (see recommendation below). Finally maps also serve as a tool to educate the public, policy makers and politicians to increase awareness of the problem.

- **Define susceptibility and how this relates to vulnerability of marine resources.** Similar to the previous breakout session, lack of clarity on the definition of susceptibility to hypoxia and acidification represents a guessing game for modelers. Workshop participants recommended a continued strengthening of the community of modelers, observational researchers, managers and stakeholders to define susceptibility (see recommendations, previous breakout). Maps, observational data, and model output can be used to facilitate a discussion about creation of indices that capture thresholds of the magnitude, extent and duration of hypoxia and acidification events that are of concern to a broad audience of managers and stakeholders.

These short-term actions would result in two important outcomes: 1) better engagement of affected stakeholders and the marine resource management community, which by nature is more multi-faceted than the ocean water quality management community, and 2) additional discussion and identification of regions or sub-regions in which more targeted forecasting should be conducted. A good example of this is recent funding to University of Washington to produce a forecast of acidification events for Oregon oyster hatcheries.

The near-term actions identified in the previous breakout session (i.e., fund data collection to support model refinement and create a central repository for observational data and model output) were found by the participants to also be applicable to this question and would put the community in a better position to address this susceptibility question.

For the long-term, participants emphasized linking long-term observational data sets with well-supported biological monitoring programs. Their thought process was that the most appropriate way to validate a model that addresses the vulnerability question is by comparison among measured acidification parameters, model output and actual biological response at several locations. This need is consistent with recommendations from the California Current Acidification Network, and is well articulated in their core principles document (c-can.msi.ucsb.edu).

APPENDIX A. WORKSHOP AGENDA

DECEMBER 10, 2013

8:30 **Welcome, Introductions and Workshop Goals** (*Steve Weisberg*, SCCWRP)
Welcome from meeting sponsors

9:00 **Present State of Hypoxia and Acidification on the US Pacific Coast**
Hypoxia – *Frances Chan*, Oregon State University
Acidification – *Jan Newton*, University of Washington

9:40 **Break**

10:00 **Management Questions that Define Modeling Needs**
Water Quality Management: Are Anthropogenic Nutrient Inputs Linked to Coastal Phytoplankton Blooms, Hypoxia, and Acidification? – *Robert Duff*, Washington Department of Ecology

Fisheries Management and Marine Spatial Planning in the Context of Coastal Hypoxia and Acidification – *Cat Kuhlman*, California Ocean Protection Council

Shellfish Management: What is My Water Going to Look Like Tomorrow? – *William Dewey*, Taylor Shellfish

Defining the Spatial and Temporal Scales at Which We Hope to Address These Problems: Moderated Discussion – *Steve Weisberg*, SCCWRP

11:30 **Status of Modeling Research in California Current Ecosystem Pacific Basin to Regional Scale**
Emanuele Di Lorenzo
Curtis Deutsch

12:15 **Lunch on Site**

1:00 **Status of West Coast Modeling Research Continued Regional to Local Scale**
Parker MacCready and Neil Banas
Alexander Kurapov
Oliver Fringer
Chris Edwards
Jim McWilliams

2:50 **Charge to Breakout Groups: Identifying the Importance of Anthropogenic Inputs to Hypoxia and Acidification** (*Steve Weisberg*)

3:00 **Break**

3:20 **Breakout Groups: Identifying the Importance of Anthropogenic Inputs to Hypoxia and Acidification**
What are the biggest impediments to model development?
- Model Infrastructure
- Boundary Condition Inputs
- Process Rate Information
- Calibration/Validation Data Sets
- Funding

5:00 **Adjourn for the Day**

6:30 **Group Dinner** – Antonello's Italian Restaurant, 3800 South Plaza Drive Santa Ana

DECEMBER 11, 2013

8:30 **Breakout Groups: Identifying the Importance of Anthropogenic Inputs to Hypoxia and Acidification** – *Continued*

9:30 **Plenary Report Out from Breakout Groups: Identifying the Importance of Anthropogenic Inputs to Hypoxia and Acidification**

10:30 **Charge to Breakout Groups: Identifying and Forecasting Susceptibility to Hypoxia and Acidification** (*Steve Weisberg*)

10:40 **Break**

11:00 **Breakout Groups: Identifying and Forecasting Susceptibility to Hypoxia and Acidification**
What are the biggest impediments to model development?
- Model Infrastructure
- Boundary Condition Inputs
- Process Rate Information
- Calibration/Validation Data Sets
- Funding

12:30 **Lunch on Site**

1:30 **Breakout Groups: Identifying and Forecasting Susceptibility to Hypoxia and Acidification** – *Continued*

3:00 **Break**

3:20 **Plenary Report Out from Breakout Groups: Identifying and Forecasting the Geographic Areas Most Susceptible to Hypoxia and Acidification**

4:30 **Summary of Workshop Findings and Next Steps**

5:00 **Adjourn**

APPENDIX B. WORKSHOP PARTICIPANTS

Neil Banas, **University of Washington**

Neil Banas is a Senior Research Scientist at the University of Washington Joint Institute for the Study of the Atmosphere and Ocean (JISAO) and Affiliate Assistant Professor in the University of Washington School of Oceanography. He is co-lead, with Parker MacCready, of the UW Coastal Modeling Group. His research focuses on modeling biophysical interactions on a range of scales from estuarine mudflats to regional continental margins, with current projects in the Pacific Northwest and Bering Sea.

António M. Baptista, **Oregon Health & Science University**

Dr. António Baptista is a faculty member in the Institute of Environmental Health at Oregon Health & Science University (OHSU). He holds an appointment as a professor in the Division Environmental and Biomolecular Systems program, of which he was the founding chairman. In July 2006, he became the Director of the Science and Technology Center for Coastal Margin Observation and Prediction. Dr. Baptista conducts interdisciplinary research on advanced information technology to improve scientific understanding of the coastal-margin environment. His CORIE project, initially established in 1996, is a pioneering coastal-margin ocean observing system for the Columbia River estuary and adjacent coast. He also provides scientific oversight for the development of ELCIRC and SELFE, state-of-the-art unstructured-grid computer models for 3D simulation of river-to-ocean circulation. Dr. Baptista holds Master's (1984) and PhD (1987) degrees in civil engineering from the Massachusetts Institute of Technology and the degree of Specialist in Maritime Hydraulics (1986) from Laboratório Nacional de Engenharia Civil in Portugal. He serves on the Scientific and Technical Advisory Committee of NSF's Ocean Observatories Initiative (OOI) and on the Independent Science Board of the California Bay-Delta Authority. He is president-elect of the Northwest Association of Networked Ocean Observing Systems (NANOOS).

Jack Barth, **Oregon State University**

Jack Barth is a professor of oceanography in Oregon State University's College of Earth, Ocean, and Atmospheric Sciences (CEOAS). He received a PhD in Oceanography in 1987 from the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution Joint Program in Oceanography. Jack's research seeks to understand the spatially and temporally variable ocean circulation, water mass structure and ecosystem response in coastal waters. He has led a number of research, technology development and ocean observing system projects off Oregon and the Pacific Northwest. Jack participated in the Global Ocean Ecosystems Dynamics (GLOBEC) Northeast Pacific and the Coastal Ocean Processes (CoOP) research programs, including serving as Chief Scientist on many interdisciplinary research cruises. His present research includes a focus on the characteristics and formation of low-oxygen zones off Oregon. Jack's research team uses autonomous underwater gliders to study this region, logging over 57,000 km of measurements over the last seven years. He presently serves on the Oregon Ocean Policy Advisory Council's (OPAC) Scientific and Technical Advisory Committee. From 2004 to 2007, Jack was a member of NSF's Observatory Steering Committee that launched the Ocean Observatories Initiative (OOI). As Project Scientist for the OOI, he is responsible for facilitating the scientific use of the OOI Endurance Array being installed off Oregon and Washington. In 2011, Jack became the Associate Dean for Research in CEOAS and in 2013 he became a Fellow of the Oceanography Society.

Jonathon Bishop, **California State Water Resources Control Board**

Jonathan Bishop received a Bachelor of Science degree in Environmental Engineering with an emphasis in water quality from Humboldt State University. Jon worked for the Los Angeles Regional Water Quality Control Board for 23 years. Some of the highlights of Jon's tenure with the Los Angeles Regional Board include the development of a new program to investigate the sources of groundwater contamination impacting drinking water wells, the development of a comprehensive water quality date management system for the Los Angeles Regional Water Quality Control Board. From 1998 to 2004 Jon led the effort to develop TMDLs in the Los Angeles Region, including the adoption of the first urban trash TMDL in the nation. In September 2004 Jon was named Executive Officer for the Los Angeles Regional Water Quality Control Board. In May of 2007 Jon accepted the position of Chief Deputy Director of the State Water Resources Control Board. During the spring and summer, Jon also works as a part-time River Guide and leads white-water-rafting trips down the Rogue River

Alexandria Boehm, **Stanford University**

Alexandria (Ali) Boehm is an associate professor in the environmental & water studies program in civil and environmental engineering at Stanford University. Boehm's research area is broadly water quality with an emphasis on coastal water quality and water and sanitation in developing countries. The work on coastal water quality is focused on understanding the sources, transformation, transport, and ecology of biocolloids - specifically fecal indicator organisms, pathogens, and phytoplankton, as well as sources and fate of nitrogen and phosphorus. The work on sanitation aims to develop microbial risk assessment models to gain a better understanding of how pathogens are transmitted to humans through their contact with water, feces, and contaminated surfaces. Boehm is involved in the Urban Water Engineering Research Center ReNUWIt and serves on the center leadership team. Her work in the center focuses on the use of wetlands and bioinfiltration systems to remove pathogens from urban water waste streams. Boehm teaches six classes at Stanford including a laboratory class on environmental health microbiology. She currently serves as the co-chair emeritus of the science advisory team for the California Ocean Protection Council, the chair of the California-Oregon Ocean Acidification & Hypoxia Blue Ribbon Panel, and is a member of the California Clean Beach Task Force.

Fei Chai, **University of Maine**

Dr. Fei Chai is a professor in the School of Marine Sciences and Climate Change Institute at the University of Maine. Dr. Chai received his PhD degree in oceanography from Duke University in 1995. Dr. Chai studies how physical and biological processes contribute to the carbon cycle, and how the biological pump transfers carbon into the deep ocean, and how climate variability affect marine ecosystems. Dr. Chai is an expert in developing and testing physical-biological models, and using the models along with observational data to address key regional and global issues and questions. Much of his work has been interdisciplinary, emphasizing physical, biogeochemical processes in the ocean and ecosystem dynamics. Dr. Chai teaches oceanography and climate change related courses at the University of Maine. He serves as committee member for several international scientific organizations and programs, prompting interdisciplinary and collaborative research projects.

Frances Chan, **Oregon State University**

Francis Chan is a marine ecologist and Assistant Research Professor in the Department of Zoology at Oregon State University in Corvallis, Oregon, USA. He received his PhD in ecology from Cornell University. His research focuses on the causes and consequences of changes to the biogeochemical cycles of marine ecosystems. His current work examines the factors that control the development of low oxygen zones in the sea and the effects that such zones have on marine organisms and the underlying chemical cycles that support ocean food webs.

Jim Cloern, **United States Geological Survey**

Jim Cloern is a senior research scientist at the United States Geological Survey (USGS) where he has worked since 1976. His research addresses comparative ecology and biogeochemistry of estuaries to understand how they respond as ecosystems to climatic-hydrologic variability and human disturbance. He leads a team investigation of San Francisco Bay that has included study of primary production, nutrient cycling, algal and zooplankton community dynamics, ecosystem metabolism and food web dynamics, disturbance by introduced species, Bay-Ocean connectivity, ecosystem restoration, and projected responses to climate change. Jim has been a Fulbright Research Scholar at the Centre d'Océanologie de Marseille, mentored 12 postdoctoral scientists and 24 graduate students from 6 countries, teaches scientific writing, is Consulting Professor at Stanford University, served as Co-Editor of Estuaries and Coasts, and received the 2010 B.H. Ketchum Award from the Woods Hole Oceanographic Institution and 2012 Brown-Nichols Award from the Delta Science Program.

Larry Crowder, **Center for Ocean Solutions**

Larry Crowder's research centers on predation and food web interactions, mechanisms underlying recruitment variation in fishes, population and food web modeling in conservation biology, and interdisciplinary approaches to marine conservation. He has studied food web processes in both freshwater and marine ecosystems, and has used observational, experimental, and modeling approaches to understand these interactions in an effort to improve management. He was principal investigator for a number of large interdisciplinary research projects including the South Atlantic Bight Recruitment Experiment (SABRE), OBIS SEAMAP (Spatial Ecological Analysis of Megavertebrate Animal Populations), and Project GLOBAL (Global Bycatch Assessment of Long-Lived Species). He has also directed and participated in a number of research, analysis, and synthesis groups at the National Center for Ecological Analysis and Synthesis (NCEAS) and for the National Research Council's Ocean Studies Board. His recent research has focused on marine conservation, including research on bycatch, spatial ecological analysis, nutrients and low oxygen, sustainable seafood, ecosystem-based management, marine spatial planning, and governance.

Kristen Davis, **University of California Irvine**

Kristen Davis is an Assistant Professor of Civil and Environmental Engineering at the University of California Irvine (UCI). She earned a BS in Environmental Engineering at the University of Florida and a MS and PhD in Civil and Environmental Engineering at Stanford University. After graduate school, Kristen received a postdoctoral scholarship to study at the Woods Hole Oceanographic Institution in the departments of Physical Oceanography and Biology and then became a Research Associate at the Applied Physics Laboratory at the University of Washington in Seattle. In her free time, she enjoys reading, diving, and hiking with her husband, daughters, and yellow lab.

Curtis Deutsch, **University of Washington**

Curtis Deutsch's research is aimed at understanding the interactions between climate and ecosystems. By combining large-scale datasets and models of varying complexity, his work has revealed new ways in which climate produces spatial pattern and temporal variability in ecosystems, and thus influences their basic functioning. Most of this work has focused on biogeochemical cycles in the ocean, with a particular emphasis on the mechanisms that regulate the cycles of nutrients and oxygen on time scales from decades to millennia. He also works at the interface between thermal physiology and terrestrial ecology to understand patterns of terrestrial biodiversity and its response to climate change. He received his B.S. from Oberlin College and a PhD from Princeton University, and is an Associate Professor at the University of Washington, in the School of Oceanography.

William Dewey, **Taylor Shellfish Company**

Since receiving his degree in shellfish biology from the University of Washington in 1981. Bill Dewey has worked for over thirty years as a shellfish farmer in Washington State. He is Manager of Public Policy and Communications for Taylor Shellfish Company, the largest producer of farmed shellfish in the United States, and owns and operates his own manila clam farm in Samish Bay, Washington. Bill has taken an active role throughout his career on environmental and human health regulations as they affect the shellfish farming community. He serves on a number of boards and committees locally and nationally including the Board of Directors of the National Aquaculture Association and the Pacific Shellfish Institute and served on Washington State's Ocean Acidification Blue Ribbon Panel in 2011.

Emanuele Di Lorenzo, **Georgia Tech University**

Graduated in 2003 at the Scripps Institution of Oceanography, Dr. Di Lorenzo was trained as a physical oceanographer and climate scientist. After moving at Georgia Tech in 2004, Dr. Di Lorenzo's research focused on large and regional scale Pacific climate dynamics, and on climate impacts on the coastal environment and marine ecosystems. His work relies on combining available observations with advanced numerical and statistical models of the large-scale ocean-atmosphere system and of the coastal ocean. Dr. Di Lorenzo is actively involved in the international community by serving on committees and chairing working groups within the North Pacific Marine Organization (PICES) and the International Council for the Exploration of the Seas (ICES). He is also active in the climate community within CLIVAR working group on ENSO Diversity and was recently appointed to the pool of expert for the United Nation World Ocean Assessment. A full bio can be found at http://ocean.eas.gatech.edu/manu.

Robert Duff, **Washington Department of Ecology**

Rob received a Bachelor of Science degree in Zoology from the University of Massachusetts at Amherst in 1986. Rob's interest's moved from cancer research to toxicology and, in 1993, he received a Master of Science degree from the Department of Environmental Health at the University of Washington in Seattle. Rob's thesis was in the field of exposure assessment investigating the dermal uptake of contaminants from soil. Following his thesis work, Rob was employed by the State of New Hampshire in the Bureau of Health Risk Assessment with duties involving risk assessment, community education, grant writing and development of regulatory standards. After moving back to Washington in 1996, Rob did similar work as a toxicologist for the Washington State Department of Health eventually becoming Director of DOH's, Office of Environmental Health Assessments where he led a team of risk assessors, toxicologists, epidemiologists and health educators towards the goal of reducing human exposure to environmental contaminants. Rob currently manages the Environmental Assessment Program at the Washington State Department to Ecology. The Environmental Assessment Program provides critical monitoring, modeling and analytical capacity to measure toxics, nutrients and bacterial contamination in both marine and freshwater aquatic environments. Assessments of these data provided by program staff are the foundation for agency decision making to protect and enhance human health and the environment in Washington State.

Richard Dugdale, **San Francisco State University**

Richard Dugdale PhD is a Senior Research Scientist at the Romberg Tiburon Center, San Francisco State University. He is a biological oceanographer interested in biogeochemical cycling. He pioneered the use of the stable isotope 15N in aquatic studies that led to the ability to separate primary production by phytoplankton based on the input of "new" nutrients versus "regenerated" nutrients. The concept allows the estimate of primary production available for export up the food chain or downward to the deep sea and sediments. His career has centered on the study of upwelling and he has >45 publications concerning coastal upwelling, most resulting from large interdisciplinary oceanographic programs. He has participated in studies of the major upwelling systems of the world, most recently in the CoOP-WEST study of the Bodega Bay upwelling region and the Gulf of the Farallones (NIMFS Rockfish survey data and RV Fulmar cruises). His current research is focused on the San Francisco Estuary and nearby offshore waters showing that elevated ammonium concentrations within the estuary results in unused ammonium and nitrate being exported to the nearby coastal waters that can be traced to the Gulf of the Farallones.

Chris Edwards, **University of California Santa Cruz**

Chris Edwards is a professor of Ocean Sciences at University of California Santa Cruz. He received his PhD in Physical Oceanography from the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution in 1997. Much of his research over the last decade focuses on physical circulation, coupled ocean ecosystem, and larval transport studies within the California Current System. His ocean modeling efforts apply the Regional Ocean Modeling System (ROMS) and include the development and implementation of a near-realtime nowcast and forecast system for the California Current System that is supported by CeNCOOS. Recent research has focused on the development of a data assimilative strategy for ocean ecosystem models that will enable improved estimates of these fields in future nowcast and forecast systems.

Richard Feely, **National Oceanic and Atmospheric Administration (NOAA)**

Dr. Richard A. Feely is a Senior Scientist at the National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory in Seattle, WA. He also holds an affiliate full professor faculty position at the University Of Washington School Of Oceanography. His major research areas are carbon cycling and ocean acidification processes in the oceans. He received a BA in Chemistry from the University of St. Thomas, in St Paul, Minnesota in 1969. He then went onto Texas A&M University where he received both an MS degree in 1971 and a PhD degree in 1974 in the field of Chemical Oceanography. He is also a member of the US Science Steering Committees for the US Carbon Cycle Science Program and the US Carbon and Biochemistry Program. He is a member of the American Geophysical Union and the American Association for the Advancement of Science. Dr. Feely has authored more than 180 refereed research publications. He was awarded the Department of Commerce Gold Award in 2006 for his pioneering research on ocean acidification. In 2007, Dr. Feely was elected to be a Fellow of the American Geophysical Union.

Oliver Fringer, **Stanford University**

Oliver Fringer is associate professor in the Department of Civil and Environmental Engineering at Stanford University, where he has been since 2003. He received his BSE from Princeton University in Aerospace Engineering and then received an MS in Aeronautics and Astronautics, followed by a PhD in Civil and Environmental Engineering, both from Stanford University. His research focuses on the application of numerical models and parallel computing to the study of laboratory- and field-scale environmental flows to understand the physics of salt and sediment transport in estuaries, internal waves and mixing, and turbulence in rivers. Oliver's interest in coastal hypoxia is related to internal wave breaking and the resulting transport of low-DO waters to the nearshore. To study this problem, Oliver and a PhD student, Robert Arthur, are working on high-resolution, three-dimensional numerical simulations of internal wave breaking on slopes to understand the physical mechanisms by which internal waves transport tracers in the cross-shore direction. Our objective is to determine simple rules for quantifying hypoxia risk with knowledge of the internal wave climate and bathymetry.

Paul Hann, **California State Water Resources Control Board**

Paul Hann worked for 10 years in industry and consulting where he was involved with air permitting, hazardous waste management, CEQA/NEPA compliance and storm water management. In 2005, Paul joined the Central Valley Regional Water Quality Control Board, developing policies related to discharges of pesticides and enforcement of the irrigated lands regulatory program. Since joining the State Water Resources Control Board, Paul supervised freshwater standards development. Recently, he became the Chief of the Wetlands, Ocean and Watershed section. This section is responsible for developing water quality standards and implementation programs to protect California's Ocean waters, as well as administering the Non-Point Source Grant Program and the 401 Water Quality Certification program.

Meredith Howard, **Southern California Coastal Water Research Project Authority**

Meredith Howard is a biological oceanographer specializing in the ecology and physiology of phytoplankton, including harmful algal blooms (HABs). Dr. Howard's current research is focused on examining the environmental factors that influence phytoplankton blooms, particularly with respect to nutrient sources that lead to the development and maintenance of algal blooms. She is also involved in research to evaluate the extent of cyanobacteria presence and toxin production in a variety of southern California estuaries, streams and other freshwater habitats. She serves on two steering committees for HABs in California, the California Harmful Algal Boom Monitoring and Alert Program (HABMAP) and the California Cyanobacteria Harmful Algal Blooms (CCHABs).

Alex Kurapov, **Oregon State University**

Alexander Kurapov obtained his PhD in Fluid Mechanics from St-Petersburg State Marine Technical University (Russia) in 1994. He was a post-doctoral researcher at Cambridge University (UK), P. P. Shirshov Institute of Oceanology (St-Petersburg, Russia), and College of Oceanic and Atmospheric Sciences, Oregon State University (COAS/OSU). He is currently an Associate Professor at COAS. His research is focused on coastal ocean circulation modeling, analysis, data assimilation, and forecasting.

Cat Kuhlman, **California Ocean Protection Council/California Resources Agency**

Cat Kuhlman was appointed in April 2012 by Governor Brown to serve as the Deputy Secretary for Ocean and Coastal Matters at the Resources Agency and as the Executive Director to the Ocean Protection Council. Previously Cat was the Executive Director for the North Coast Water Quality Control Board, which is responsible for protecting and restoring water quality on the North Coast, including the coastline and major rivers from the Russian to the Smith. Before coming to the Board, Cat worked for the USEPA managing diverse environmental problems along the US-Mexico border as well as a wide variety of federal water programs including the Clean Water, Safe Drinking Water Act and Marine Protection, Research and Sanctuaries Act. A water enthusiast, Cat has written papers on international environmental issues, and water quality standards. She and her husband love to explore streams and loaf on beaches.

John Largier, **University of California Davis/Bodega Bay Marine Laboratory**

John Largier is Professor of Coastal Oceanography at the University of California Davis (UCD), resident at Bodega Marine Laboratory. Prior to 2004, he was Research Oceanographer at Scripps Institution of Oceanography. He has also held positions at the University of Cape Town and the National Research Institute for Oceanology (CSIR) in South Africa. His research, teaching and public service is motivated by contemporary environmental issues and centered on the role of transport in ocean, bay, nearshore and estuarine waters. His work has addressed transport of plankton, larvae, contaminants, pathogens, heat, salt, nutrients, dissolved oxygen, and sediment – and he places this work in the context of diverse management issues. At UCD he heads the 16-person Coastal Oceanography Group. Dr Largier is a leader in developing the field of "environmental oceanography" through linking traditional oceanographic study to critical environmental issues. Dr Largier serves on the Science Advisory Team for the California Marine Life Protection Act (MLPA), the Governing Council for CeNCOOS (Central and Northern California Ocean Observing System), the Sanctuary Advisory Committee for the Gulf of Farallones, and several other advisory boards.

Lisa Lucas, **United States Geological Survey**

Lisa Lucas is an eco-hydrodynamicist with the United States Geological Survey (USGS). Inhabiting the interface between physics and biology in aquatic ecosystems, she studies how interactions between hydrodynamics and other physical and biological processes influence the base of the aquatic food web (namely, phytoplankton). She primarily works in tidal systems like San Francisco Bay, employing numerical models and field measurements (ideally, together) to improve understanding of how these ecosystems work and to support informed ecosystem management. Lisa currently co-leads "CASCaDE" (Computational Assessments of Scenarios of Change for the Delta Ecosystem). This hyper-disciplinary modeling project aims to develop and link several numerical models of the San Francisco Bay-Delta-Watershed-Atmosphere system. The goal is to assess plausible scenarios of change over the coming century for the Sacramento-San Joaquin Delta, the fragile freshwater ecosystem at the head of San Francisco Bay and the hub of California's water delivery system.

Parker MacCready, **University of Washington**

Dr. Parker MacCready is a Physical Oceanographer at the University of Washington, specializing in estuarine and coastal work. With Dr. Neil Banas he leads the University of Washington Coastal Modeling Group (faculty.washington.edu/pmacc/cmg/cmg.html) developing realistic numerical simulations of ocean circulation and biogeochemistry. Current projects in the CMG address flow-topography interactions, river plumes, Harmful Algal Blooms, hypoxia, ocean acidification, and the effects of global climate change on regional scales. Dr. MacCready is working as a Visiting Scientist at Microsoft Research until February 2014.

Jim McWilliams, **University of California Los Angeles**

Jim McWilliams received his university degrees in Applied Mathematics: a B.S. (with honors) in 1968 from Caltech and an MS in 1969 and PhD in 1971 from Harvard. After holding a Research Fellowship in Geophysical Fluid Dynamics at Harvard (1971-74), he worked at the National Center for Atmospheric Research (NCAR), where he became a Senior Scientist in 1980. In 1994 he became the Louis Slichter Professor of Earth Sciences at University of California Los Angeles (UCLA). He has served as a scientific advisor for many organizations; in particular, in 2001 he was a member of the NRC Climate Change Science Committee that reported to the United States President on global warming and in 2012 was a member of the NRC Sea Level Rise assessment for the West Coast Governors. His primary area of scientific research is the fluid dynamics of Earth's oceans and atmosphere. He is a member of the National Academy of Sciences.

Karen McLaughlin, **Southern California Coastal Water Research Project Authority**

Karen McLaughlin is a senior scientist at Southern California Coastal Water Research Project Authority (SCCWRP), specializing in nutrient cycling and source tracking in coastal waters. Dr. McLaughlin's current research utilizes novel tracer techniques to understand the source and fate of anthropogenic nutrients on coastal waters. She is particularly interested in understanding the effects of productivity on nutrient cycling, hypoxia, acidification, and use of stable isotope tracers for evaluating relative influence of different nutrient sources to ecosystems. She also conducts research on understanding factors and processes controlling ecosystem response to nutrient loading, development of assessment tools for eutrophication, and understanding "background" contribution of nutrients from atmospheric deposition and groundwater. She is currently serving as facilitator for the California Current Acidification Network (C-CAN), helping to coordinate monitoring efforts for nearshore acidification on the US West Coast. She received her BS in Geosciences from Penn State University in 1999, her PhD in Geological and Environmental Sciences from Stanford University in 2005, and completed a post-doctoral assistantship at the University of California Irvine in 2007.

Fiorenza Micheli, **Hopkins Marine Laboratory**

Fiorenza Micheli is a marine ecologist and conservation biologist conducting research and teaching at the Hopkins Marine Station of Stanford University, in California, USA, where she is Professor of Biology. Her research focuses on the processes shaping marine communities, and incorporating this understanding in the management and conservation of marine ecosystems. Current research focuses on responses of marine communities to climate change, and on the function of marine protected areas and other conservation and adaptation strategies in the face of climate impacts. She is the PI on the project "Enhancing resilience of coastal ecosystems and human communities to oceanographic variability: social and ecological feedbacks" funded by the National Science Foundation Coupled Natural-Human Systems. She received her undergraduate degree in natural sciences from the University of Florence, Italy, in 1988, and a PhD in marine sciences from the University of North Carolina at Chapel Hill, USA, in 1995. She has conducted research in Italy, east Africa, Australia, the Bahamas, Mexico, California, and the Pacific Line Islands, in a suite of marine ecosystems including mangrove forests, seagrass beds, salt marshes, rocky reefs, coral reefs, pelagic systems, and deep sea hydrothermal vents. Professor Micheli is a fellow of the California Academy of Science and the Aldo Leopold Leadership Program, a Pew fellow in marine conservation, and past president of the Western Society of Naturalists.

Steve Monismith, **Stanford University**

Dr. Steve Monismith is currently director of the Environmental Fluid Mechanics Laboratory. Prior to coming to Stanford, he spent three years in Perth (Australia) as a research fellow at the University of Western Australia. His research in environmental and geophysical fluid dynamics involves the application of fluid mechanics principles to the analysis of flow processes operating in rivers, lakes, estuaries and the oceans. Making use of laboratory experimentation, numerical modelling, and field measurements, his current research includes studies of estuarine hydrodynamics and mixing processes, flows over coral reefs, wind wave-turbulent flow interactions in the upper ocean, turbulence in density stratified fluids, and physical-biological interactions in phytoplankton and benthic systems. Because his interest in estuarine processes is intertwined with an interest in California water policy issues, he has been involved with efforts at developing management strategies for improving the "health" of the San Francisco Bay through regulation of freshwater flow into the Bay.

Jan Newton, **University of Washington**

Dr. Jan Newton is a Principal Oceanographer with the Applied Physics Laboratory of the University of Washington and affiliate faculty with the UW School of Oceanography and the School of Marine and Environmental Affairs, both in the UW College of the Environment. She is the Executive Director of the Northwest Association of Networked Ocean Observing Systems (NANOOS), the US IOOS Regional Association for the Pacific Northwest. Jan is a biological oceanographer who has studied the physical, chemical, and biological dynamics of Puget Sound and coastal Washington, including understanding effects from climate and humans on water properties. Currently she has been working with colleagues at UW and NOAA to assess the status of ocean acidification in our local waters.

Mindy Roberts, **Washington Department of Ecology**

Mindy Roberts is an environmental engineer with the Washington State Department of Ecology's Environmental Assessment Program. She manages several large studies that analyze human impacts on Puget Sound as well as the region's lakes and rivers. She has a BS in Civil Engineering from the University of California, Berkeley, an MS in Civil and Oceanographic Engineering from the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, and a PhD in Civil and Environmental Engineering from the University of Washington. She has over 20 years of experience working on complex scientific studies and computer model applications. Mindy is a registered professional engineer in the State of Washington and the Commonwealth of Massachusetts.

Leslie Rosenfeld, **Monterey Bay Aquarium Research Institute**

Dr. Leslie Rosenfeld has been the Program Director of the Central and Northern California Ocean Observing System (CeNCOOS) since September 2011. She is responsible for coordinating a variety of ocean and atmospheric observing and modeling activities, and management and communication of resulting data and information products. She has a PhD in Physical Oceanography, and specialized in circulation over the California continental shelf during her research career. She has conducted field studies, many of them interdisciplinary, off northern, central, and southern California, and has worked closely with numerical modelers on many of these projects. Since arriving in California in 1989, to work at the Monterey Bay Aquarium Research Institute (MBARI) and the Naval Postgraduate School, she has been involved in the planning and implementation of coastal ocean observing. In addition to her research and consulting work, Dr. Rosenfeld also has extensive teaching experience, and has been involved in ocean workforce development efforts. She brings experience with a range of coastal and marine management issues facing California, and in the utilization of scientific data to address those issues.

Samantha Siedlecki, **University of Washington**

Samantha Siedlecki obtained her PhD from University of Chicago in 2010. She worked with David Archer and Amala Mahadevan on idealized simulations of nutrients, methane, and iron. In her dissertation, new mechanisms were identified for nitrate supply from the open ocean and gas exchange on the east coast of the US, and export of iron in upwelling systems, like the west coast of the US. As a Post-Doctoral Fellow at the Joint Institute for the Study of Atmosphere and Oceanography (JISAO) at the University of Washington, she worked with the Coastal Modeling Group to develop a regional model for oxygen for the Washington and Oregon coasts. (faculty.washington.edu/sarahgid/PNWTOX/resultsHypoxia.html). That model was used to hindcast 2005-2007 and forecast 2013 through the J-SCOPE project (http://www.nanoos.org/products/j-scope/home.php). Currently, she is a research scientist working on adding inorganic carbon dynamics to that model as well as an existing model for the Gulf of Alaska.

David Senn, **San Francisco Estuary Institute**

David Senn is a Senior Scientist at the San Francisco Estuary Institute (SFEI). He received his PhD in environmental engineering from MIT, where he studied the interactions between nitrogen pollution and iron and arsenic cycling in contaminated urban lakes. Subsequently, as a researcher at the Harvard School of Public Health, he conducted contaminant fate, transport, and exposure studies, including investigating mercury cycling, bioaccumulation, and human exposure in the Gulf of Mexico. Prior to joining SFEI in 2011, he worked at the Swiss Federal Institute of Aquatic Science and Technology (Eawag), studying the impacts of large dams in the Zambezi River Basin in southern Africa.

Martha Sutula, **Southern California Coastal Water Research Project Authority**

Martha Sutula is head of the Biogeochemistry Department at the Southern California Coastal Water Research Project Authority (SCCWRP), a research institute formed by the leading water quality management agencies in California to ensure a solid scientific foundation for their activities. Dr. Sutula oversees research related to eutrophication and harmful algal blooms in streams, estuaries and nearshore waters, tracking sources and fate of contaminants including stormwater and atmospheric deposition, remote sensing, and water quality modeling. Beyond her research activities, she focuses on linking science to management. Examples of this include her work as lead scientist to the California State Water Board providing technical support to develop nutrient objectives. Dr. Sutula is President of California Estuarine Research Society and serves on numerous scientific advisory panels such as the California-Oregon Ocean Acidification & Hypoxia Blue Ribbon Panel and the Pacific Marine and Estuarine Fish Habitat Partnership. She received her undergraduate degree in Chemistry from Purdue University, her Masters of Public Health from Tulane University, and her Ph.D. from the Department of Oceanography and Coastal Sciences, Louisiana State University.

Libe Washburn, University of California Santa Barbara

Libe Washburn is an oceanographer and professor working at the University of California, Santa Barbara (UCSB) in the Department of Geography. He is also chair of the UCSB Interdepartmental Graduate Program in Marine Science. His educational background is in engineering and he worked for a few years in industry as an aerospace engineer. His main research interests focus on interdisciplinary links between ocean circulation processes and marine communities in a variety of ocean environments. Collaborators in this work are marine ecologists and oceanographers at several institutions. Washburn's research is based on observations and he employs a variety of approaches in his work including oceanographic moorings, research vessels, ocean gliders, and high frequency (HF) radar for mapping surface currents. He currently has research projects focused on circulation along the California coast, ocean acidification, and development of a coastal ocean observing system in California. He is also an associate investigator in the Santa Barbara Coastal and Moorea Coral Reef Long Term Ecological Research (LTER) projects. Marine pollution is a long-standing research interest and he has previously worked with other oceanographers and microbiologists in a study of pollution from coastal wastewater outfalls in California. He is an active participant in the evolving coastal ocean observing systems and is the chair of the Board of Governors of the Southern California Coastal Ocean Observing System (www.sccoos.org). More information about his oceanographic research is available at http://www.msi.ucsb.edu/people/faculty/libe-washburn.

Stephen Weisberg, Southern California Coastal Water Research Project Authority

Dr. Stephen Weisberg is Executive Director of the Southern California Coastal Water Research Project Authority (SCCWRP), a research consortium formed by the leading water quality management agencies in California to ensure a solid scientific foundation for their activities. Dr. Weisberg's research emphasis is in developing molecular assessment tools to support environmental monitoring programs. Beyond his research activities, Dr. Weisberg focuses on at linking the needs of the management community with science. He specializes in translating science into management action and brings with him the management perspectives he gains through interactions with his multiple member agencies. Dr. Weisberg serves on the Governing Boards of the California Ocean Science Trust and the Southern California Coastal Ocean Observing System. He also serves on numerous advisory committees, including the State of California's Clean Beach Task Force, the California Ocean Protection Council Science Advisory Team, and California Sea Grant Program Advisory Council. Dr. Weisberg received his undergraduate degree from the University of Michigan and his PhD from the University of Delaware.

Brock Woodson, University of Georgia

Dr. Woodson is a coastal oceanographer and engineer located at the University of Georgia, and a research affiliate at the Center for Ocean Solutions. His background is in physical oceanography, fine-scale fluid dynamics, and zooplankton foraging ecology. He was the lead developer of the Kelp Forest Array (KFA), a shallow-water undersea cabled research platform, and now currently acts as a KFA science advisor. He works on shelf hypoxia along the California Current system, primarily in Baja California and in the Monterey Bay region. Currently his group is developing nearshore models of hypoxia development aimed at providing forecasts for coastal ocean managers, and evaluating the need for numerical or statistical models to address policy needs. Other projects include Monterey Bay coastal circulation, behavioral responses of coastal fishes to periodic hypoxia using sonar, development of a front-parameterized ecosystem model, and assessment of sustainable energy alternatives (wind and wave energy) on coastal ecosystems.

SCCWRP Established 1969

CENTER FOR OCEAN SOLUTIONS

CALIFORNIA OST Ocean Science Trust
Connecting Science to Ocean Management

Headquarters
99 Pacific Street, Suite 555E
Monterey, CA 93940
Phone: 831-333-2077
Fax: 831-333-2081

Stanford University Office
473 Via Ortega, Room 193
Stanford, CA 94305
Phone: 650-725-9475
Fax: 650-721-2957

www.centerforoceansolutions.org